3.5.1 Newton's laws of motion

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	Newton's three laws of motion	HSW7
(b)	linear momentum; $p = mv$; vector nature of momentum	
(c)	net force = rate of change of momentum; $F = \frac{\Delta p}{\Delta t}$	Learners are expected to know that $F = ma$ is a special case of this equation. HSW9, 10 *M2.1, M3.9*
(d)	impulse of a force; impulse = $F\Delta t$	
(e)	impulse is equal to the area under a force–time graph.	Learners will also be expected to estimate the area under non-linear graphs. HSW3 Using a spreadsheet to determine impulse from F–t graph. *M3.8, M4.3*

3.5.2 Collisions

	Learning outcomes	Additional guidance
	Learners should be able to demonstrate and apply their knowledge and understanding of:	
(a)	the principle of conservation of momentum	HSW7
(b)	collisions and interaction of bodies in one dimension and in two dimensions	Two-dimensional problems will only be assessed at A level. HSW11, 12
(c)	perfectly elastic collision and inelastic collision.	HSW1, 2, 6

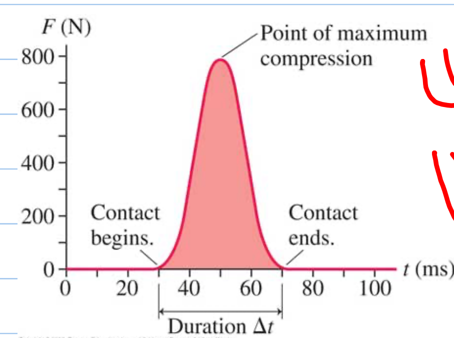
(6) M - Define impulse
(7) S - recall and apply the equation impulse = change in momentum
(8) C - Find accuratly the impulse from a graph of force against time.

Impulse

STARTER: Sketch a resultant force against time graph on a football, initially stationary and then kicked.

F t

Extension: What is impulse? How can it be calculated from this graph?



- The force accelerating or decelerating an object usually changes over time.
- Can you think of situations where a constant force is applied and where a changing force is applied?

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Impulse

Key definition: Impulse

$\boxed{\text{Force x time for which the force acts} \\ \text{OR} \quad F\Delta t \text{ with both symbols defined}}$

Force x time for which the force acts

OR FΔt with both symbols defined

$$F = \frac{\Delta p}{\Delta t}$$

N, kgms⁻¹, s

$F\Delta t = \Delta p = \text{Impulse}.$ Ns

Question:

A stationary 50g squash ball experiences an impulse of 1.1Ns.

Calculate its final velocity

$\Delta p = 1.1\,\text{Ns} = (V - U)m$

$\frac{1.1}{m} = \frac{1.1}{0.05} = 22\ \text{ms}^{-1}$

Ex: Why can't we use F=ma for this to find a and then find V?

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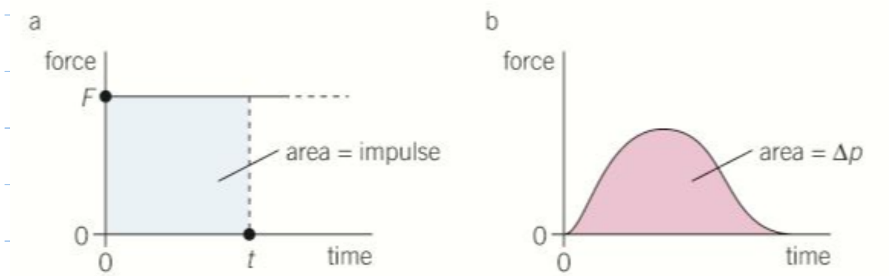
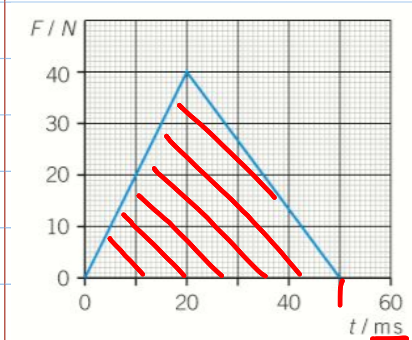
(8) C - Find accuratly the impulse from a graph of force against time.

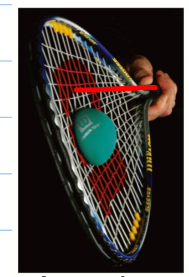
Impulse = area under a force against time graph.

Explain why using the graphs below?



Example 1: Easy grap





A stationary squash ball of 25g.

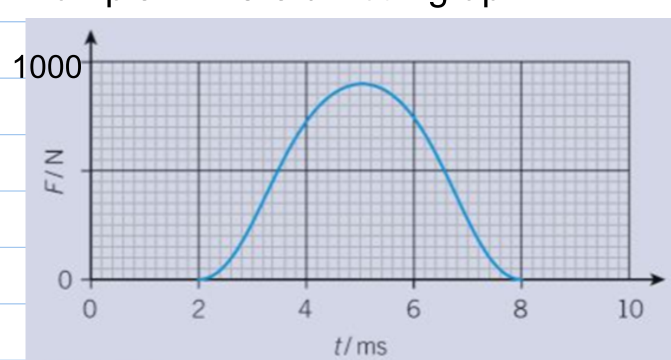
Q1: Calculate the final speed of the ball.

$\text{Area} = \frac{1}{2} \times \text{base} \times \text{height} = \frac{1}{2} \times 0.05 \times 40 = 1\ \text{Ns}$

$\text{Impulse} = (v - u)m = 1$

$v = \frac{1}{0.025} = 40\ \text{ms}^{-1}$

Example 2: More difficult grap



a) Find the impulse

b) Find the final speed of the same ball

(6) M - Define impulse
(7) S - recall and apply the equation impulse = change in momentum
(8) C - Find accuratly the impulse from a graph of force against time.

Demo impulse.

Use the data e-mailed to you to find the impulse in situation a) with no crumple zone b) with a crumple zone.

What do you notice?

Ex: Use the information to explain the need for a crumple zone.

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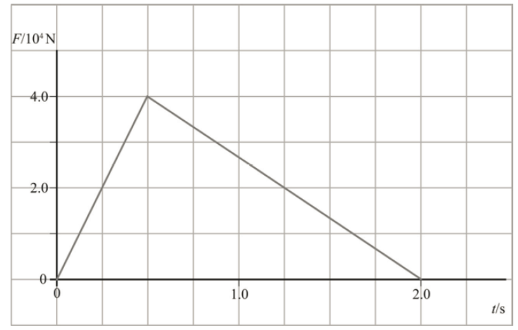
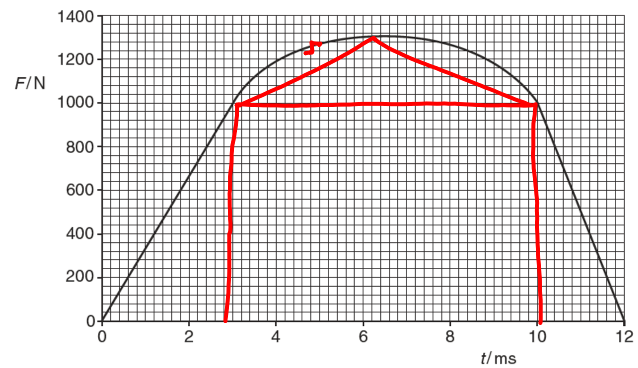
Impulse practice questions.
Ex: Continue with the summary questions on page

9 A 900 kg car crashes into a safety barrier. The diagram below show how the force F acting on the car changes with time t while the car is being stopped.
The final velocity of the car is zero.



a Use the graph above to determine the impulse of the force. [3]
b Calculate the initial velocity of the car. [3]

A small rocket is used to detach a satellite of mass 180 kg from the spacecraft. Fig. 2.2 shows the variation of the force F created by the rocket on the satellite with time t.



(i) determine the change in the velocity of the satellite as a result of the force F applied for the period of 12 ms.

change in velocity = ... m s^{-1} **[4]**

(ii) describe how the acceleration of the satellite varies between 0 and 10 ms.

....

....

....

....

.... **[2]**

(6) M - Define impulse
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Impulse practice questions
MS

9 a Impulse = area under force against time graph [1]

impulse = $\frac{1}{2} \times 4.0 \times 10^4 \times 2.0$ [1]

impulse = 4.0×10^4 N s [1]

b Change in momentum = impulse = 4.0×10^4 kg m s^{-1} [1]

$mv = 4.0 \times 10^4$ (final momentum of car = 0) [1]

$v = \frac{4.0 \times 10^4}{900} = 44.4 \text{ m s}^{-1} \approx 44 \text{ m s}^{-1}$ [1]

(b)	(i)	Area under graph in range 10.5 to 11.5 (Ns) Area under graph in range 10.8 to 11.2 (Ns) $\Delta v = \frac{\text{impulse}}{m} = \frac{\text{area}}{m}$ $= \frac{11.0}{180}$ $= 6.1 \times 10^{-2}$ (ms^{-1})	C1 C1 C1 A1	Possible FT fo Use of mass o marks.
	(ii)	From 0 to 3 (ms) acceleration increases linearly/uniformly/ at constant rate/ at a steady rate. (From 6.5 ms) onwards/later/at end the acceleration decreases	B1 B1	**Allow:** upper li Do not credit u **Not 'decelerat**

(i) determine the change in the velocity of the satellite as a result of the force *F* applied for the period of 12 ms.

change in velocity = ... m s^{-1} **[4]**

(ii) describe how the acceleration of the satellite varies between 0 and 10 ms.

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Plenary

impulse	when two objects interact, they exert equal and opposite forces on each other
Newton's second law	rate of change of momentum
net force	the resultant force acting on an object is directly proportional to the rate of change of its momentum, and is in the same direction
Newton's first law	an object will remain at rest or continue moving with constant velocity unless acted upon by a resultant force
Newton's third law	the area under a force–time graph

Statement	True/False
Total kinetic energy in an inelastic collision is conserved.	
Magnitude of the impulse on each object in an inelastic collision is the same.	
Total momentum for the objects in an elastic collision is conserved.	
Total energy in an inelastic collision is conserved.	

(i) determine the change in the velocity of the satellite as a result of the force *F* applied for the period of 12 ms.

change in velocity = ... m s^{-1} **[4]**

(ii) describe how the acceleration of the satellite varies between 0 and 10 ms.

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